AU/ACSC/183/1999-04

AIR COMMAND AND STAFF COLLEGE

AIR UNIVERSITY

IMPROVING F-15C AIR COMBAT TRAINING WITH DISTRIBUTED MISSION TRAINING (DMT) ADVANCED SIMULATION

by

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A Research Report Submitted to the Faculty

In Partial Fulfillment of the Graduation Requirements

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Maxwell Air Force Base, Alabama

April 1999

Disclaimer

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Preface

My interest in air combat simulator training began as a practical problem while serving as the Fighter Weapons Phase Head for the F/A-18 Fleet Readiness Squadron (Fighter Training Unit equivalent) on a three-year Navy exchange tour at Lemoore NAS, California. While overhauling their air-to-air syllabus, I was allocated a limited number of syllabus-hours to train students in networked F/A-18 simulators. The simulators were enclosed in spherically shaped rooms, providing a realistic cockpit field-of-view. I was pelted with suggestions from other instructors on how the simulators should be used in the new training plan. Unfortunately, opinion was the only data source for decision making—there was no documented guidance on how to improve air combat training through simulation.

This document is presented to serve as a knowledge base for those endeavoring to develop F-15C syllabuses for Distributed Mission Training (DMT). Armed with lessons learned from years of simulator study, F-15C wings can develop effective and credible training programs. Blending the best features of both DMT and flight training into effective training programs will be key for swaying pilots who currently shun expansion of simulator training.

I owe a great deal of thanks for the insights of Dr. Herbert Bell and Dr. Ronald Dunlap at the Air Force Research Laboratory, and Lt Col "Taco" Bell at the 33rd Fighter Wing at Eglin AFB. I also want to thank Maj "Slap" Maxwell at HQ ACC/DOTO, and many folks at the 29th Training

Systems Squadron—specifically Lt Col Mike Graham, Mr. Jeff Wakefield, Mr. Rick Griffin, and Rick “Slick” Eplett—for their assistance. I must also thank Col Chenoweth for his guidance in this project, helping me narrow my focus into something useful for the Combat Air Forces (CAF). Finally, my family deserves the greatest thanks, for their endless patience and encouragement.

Abstract

Air Combat Command is investing in Distributed Mission Training (DMT) to provide realistic mission training to the Combat Air Forces (CAF) using advances in simulation technology. DMT will network advanced simulators (and some real-world systems) to provide combat aircrews with team training in a synthetic wartime environment. F-15C units will be first in the CAF to incorporate DMT; they are confronted with developing training programs utilizing this new tool without previous experience of how to exploit the benefits of simulation for air combat training. This paper seeks to assist syllabus developers by providing a summary of lessons learned from years of air combat simulation study, and applying those lessons to DMT.

A comprehensive analysis of air combat simulation training studies provides insight on how to improve F-15C air combat training using DMT. Studies not only demonstrate simulators can provide effective training, but also identify unique benefits and limitations of simulator training, and offer several training program considerations to achieve the most effective results. DMT benefits not available in flight training include unique instruction options, the capability to repeatedly practice desired tasks or missions, and the opportunity to train in complex combat scenarios. Identified limitations include sources of negative training and the lack of physiological stresses or inputs that may be desired in training. For training programs, simulator studies suggest which tasks should be emphasized in DMT, how metrics can identify training

needs, who is expected to gain the most benefit from DMT, and how to intermix DMT and flight scheduling to optimize training.

Chapter 1

Introduction

I am convinced Modeling and simulation Technologies available today will enable us to significantly change the way we train in the future.... We need to take a hard look at how this technology will change our training philosophy ...

—General Michael E. Ryan

The DMT Vision

Air Combat Command (ACC), while making tremendous improvements in aircraft and weapons capabilities, is beginning to outgrow its contemporary means of training. Flight training is no longer sufficient for preparing combat crews for the complexities of modern warfare. “Safety considerations, mission complexity, airspace and range restrictions, real-world commitments, and cost limit the effectiveness of live flying training opportunities.”[1] To help compensate for these limitations, ACC is investing in Distributed Mission Training (DMT) to provide realistic mission training to the Combat Air Forces (CAF) using advances in simulation technology.[2]

DMT will network advanced simulators (and some real-world systems) to provide combat aircrews with team training in a synthetic wartime environment, no longer restricting training to single-ship operations. Mission Training Centers (MTC) will house multiple simulators for each weapon system, to be used for individual and team training. DMT will also combine MTCs in a wide-area network, allowing *inter-team* training such as composite-force and AEF missions. The wide-area network will be managed by a Distributed Warfighting Center (DWC) allowing *distributed events* (between MTCs) and *stand-alone events* (within a single MTC) to be conducted concurrently. During all training events, additional forces (both adversary and friendly) can be represented by human-controlled *interactive* threat stations, or by computer-controlled *constructive* simulations. Eventually, personnel using their real-world operational systems (such as command and control systems) will also be integrated as *live* participants in DMT.[3] (MTC capabilities and the DMT expansion plan are elaborated in Appendix A and B, respectively.)

A New Training Tool

It is possible that a presumed utility of simulators may stifle innovations to make best use of DMT. In the past, simulators were used primarily for single-ship training, "to learn some basics about the weapon system, learn how to start the motor, how to employ the radar, learn which button does what; but [not to] learn the essence of [the fighter] business, which is team combat."[4] DMT finally provides the CAF with the capability for team training, providing seemingly endless possibilities for air combat training. Because DMT will seem so realistic, a natural tendency may be to treat MTC simulators just like real aircraft. But simulators are not the same as aircraft—simulators may be limited in some respects, yet may have some capabilities *beyond* those of flight training that can be exploited to improve training.

MTC accreditation will identify some of these differences by evaluating how accurately the system simulates real-world interactions, such as "the quality of the visual cues, accuracy of the sensor presentations, environmental factors, validity of threat models, fidelity of the cockpit, and the overall hardware/software capabilities."[5] ACC will then use these evaluation results to decide how DMT can contribute to annual training and proficiency requirements.[6] Accreditation will therefore determine some MTC limitations and allowable use for accomplishing Ready Aircrew Program (RAP) sorties and events, but will not dictate *how* combat units will use DMT on a daily basis for its continuation training (CT). Operational units are responsible for developing their own *training profiles* and programs for DMT, "based on expected wartime tasking, employment concepts, and MAJCOM training policy."[7] They are faced with the challenge of utilizing this new training tool without previous experience of how to exploit DMT benefits or avoid its limitations.

Although operational units have never had access to networked simulators for daily training, simulators have been used over the last 20 years for specialized air combat training. In fact, many studies have been conducted to measure the effectiveness of this simulator training. The purpose of this paper is to propose how F-15C air combat training can be improved by applying lessons learned from previous simulator training studies to DMT.

A comprehensive review of documented air-to-air simulator training research will be presented to uncover lessons applicable to future training plans incorporating DMT. A description of the simulator facilities, participants, procedures, and results will be presented for each study. In many cases interesting secondary findings or study discussions provide additional insight for improving air combat simulator training. The studies not only demonstrate that simulators can provide effective training, but also identify unique benefits and limitations of simulator training, who achieves the most benefit from such training, what tasks are best accomplished in simulation, and how simulator and flight training should be intermixed to maximize learning.

This paper will address the implications of these findings for DMT. DMT may be laden with the flaws and limitations of past and current simulators. This investigation will attempt to identify such flaws by comparing DMT simulator hardware specifications to those recommended in previous studies. Also, due to the lack of experience by operational units with network capable simulators, it is plausible that many assumptions about the utility of the new training devices will lead to less than optimum training strategies, reducing the potential effectiveness of DMT. This investigation will search for training strategies suggested in air combat training effectiveness studies that can be incorporated into F-15C training plans for DMT.

Once units determine how best to exploit DMT, they will be better able to determine an effective balance of aircraft and simulator sorties to prepare pilots for combat. Although this report specifically addresses air combat training for F-15C units, findings are likely to have implications for nearly all CAF fighters, providing them a foundation for developing effective training plans as they are integrated into the CAF-wide DMT network.

Notes

[1] Air Combat Command, Operations and Training Branch (HQ ACC/DOTO), "Concept of Operations for Distributed Mission Training," 13 October 1998, 19.

Notes

[2] Gen Richard E. Hawley, commander, Air Combat Command, address to the National Training Systems Association 19th Interservice/Industry Training Simulation and Education Conference, Orlando, Fla., 2 December 1997.

[3] HQ ACC/DOTO, "Concept of Operations for Distributed Mission Training."

[4] Hawley.

[5] Air Combat Command, Operations and Training Branch (HQ ACC/DOTO), "Concept of Operations for F-15C Mission Training Centers," Working Draft, 29 September 1998, 25.

[6] Ibid., 22.

[7] Ibid., 20.

Chapter 2

Review of Simulator Training Studies

Simulator studies can be divided into three categories: utility evaluations, in-simulator learning studies, and transfer of training studies.[1] Utility evaluations are the most basic of the three, conducted by survey to analyze pilot opinions of simulator training. In-simulator learning (ISL) studies demonstrate learning achieved within a simulator environment by measuring improvements in performance, while transfer of training (TOT) studies demonstrate improved *flight* performance due to simulator training.

Utility Evaluations

Early ACES Surveys in the SAAC

The earliest utility evaluations involved nothing more than simple aircrew surveys conducted after training in the Simulator for Air-to-Air Combat (SAAC). The SAAC combined two F-4 cockpits for training one-versus-one basic fighter maneuvers (BFM), or two-versus-one air combat maneuvers (ACM) against a constructive (computer-controlled) threat. Cockpit visual displays provided 296-degree horizontal and 150-degree vertical field of view.[2]

Tactical Air Command (TAC) conducted one-week Air Combat Engagement Simulation (ACES) courses for mission-ready (MR) pilots using the SAAC in the late 1970's. Several surveys indicated ACES BFM and ACM training was effective.[3] "The overwhelming consensus from the participants was that the training was quite valuable."[4] Although these early surveys were encouraging, they did not provide insight to improve training; later studies were conducted looking specifically for ways to improve air combat simulator training.

MACAIR Utility Evaluations

From 1988 to 1990, Armstrong Laboratory (now Air Force Resources Laboratory, AFRL) conducted two detailed surveys at what was the McDonnell Aircraft (MACAIR) simulation facility in St. Louis, Missouri. This facility combined a weapons director (WD) station with two F-15 cockpits suspended in 40-foot domes providing pilots "with a nearly full field of view."[5] Less sophisticated simulator cockpits were available for controlling interactive threats against the F-15 pilots. Constructive threats were combined with interactive threats in each scenario, challenging F-15 pilots with a large number of adversaries. The facilities allowed pilots to conduct multi-ship training against multiple air and surface-to-air missile (SAM) threats in a variety of unrestricted air combat missions.[6]

The two studies involved a total of 136 MR F-15A/C pilots.[7] After one week of MACAIR simulator training, pilots were asked to rate the value of both their unit continuation training (CT) and the F-15 simulator training for a number of combat tasks. Ratings were based on a five-point scale from 1-"Unacceptable" to 5-"Excellent." The results not only indicated the training was worth while, but also identified many combat tasks perceived to be *better trained in* *the simulators* than in CT. These tasks also received a CT value rating of less than 3-"Adequate." The tasks found better suited for simulator training are listed in table 1. Simulator training was also perceived as highly valuable for other tasks, but not necessarily more valuable than CT.[8]

Table 1. MACAIR Simulator Training Ratings of Combat Tasks

Better Trained in the Simulator	Highly Valuable Simulator Training
Multibogey, Four or More	All-Aspect Defense
Reaction to SAMs	BVR Employment
Dissimilar Air Combat Tactics	Radar Sorting
All-Weather Employment	Reaction to Air Interceptors
ECM/ECCM Employment	Missile Employment
Communications Jamming	Egress Tactics
Low Altitude Tactics	
Chaff/Flare Employment	
Escort Tactics	
Tactical Electronic Warfare System Assessment	
Work with WD	

Source: Adapted from Michael R. Houck, Gary S. Thomas, and Herbert H. Bell, *Training Evaluation of the F-15 Advanced Air Combat Simulation* (Williams Air Force Base, AZ: Armstrong Laboratory, Aircrew Training Research Division, September 1991), table 6,10.

Overall, the simulator training value was rated "quite uniformly across pilot background variables with the exception of a few tasks which were rated significantly higher by low-time pilots: Visual Identification, Electronic Countermeasures/Electronic Counter-Countermeasures (ECM/ECCM) Employment, and Reaction to SAMs. In summary, the rating data indicate much agreement among CONUS F-15 pilots regarding their perception of their training needs."[9]

Pilots also rated what they thought the benefit would be for pilots of other experience levels, using a scale from 1-"Not Beneficial" to 5-"Extremely Beneficial." The simulator training was rated "Highly Beneficial" (4.2 or better) for all experience levels with the exception of new wingman—rated only “Very Beneficial” (3.8 mean rating). Further analysis determined that four-ship leads were the primary source of lower ratings for new wingmen. “Four-ship leads rated the benefit of ... training lower for new wingmen than did the wingman themselves,” commenting that the MACAIR training “may be too demanding for a new wingman.”[10]

Combining tasks into a realistic, complex scenario enhanced training. “Overwhelmingly, pilots thought the mission scenarios were the key ingredient to the training value ... being challenging, demanding, realistic, and providing appropriate numbers of air threats for multibogey training.”[11] The ability to practice these scenarios numerous times were also found to be a unique benefit of the simulator training. “Pilots benefited greatly from repeated exposures to the same scenarios, and considered the variety of scenarios available in the simulator to be a major advantage.”[12]

“An especially important advantage of simulator-based training was the availability of immediate performance feedback that is not available in airborne training.”[13] Real-time kill removal allowed pilots to verify properly flown tactics, and see the consequences of poorly executed tactics or weapons employment.

In addition to pilot-identified benefits of the simulator training, the study also listed simulation features perceived to be unrealistic or potential sources of negative training (producing undesirable habits or behaviors[14]). The list primarily identified hardware and software deficiencies specific to the MACAIR facility: [15]

1. Red/white color changes of projected aircraft images were confusing and projections allowed tallies at unrealistic distances
2. F-15A/C pilots had to adapt to a modified F-15E simulator cockpit

3. Visually accommodating and resolving projected targets was difficult
4. Information provided by WDs was too precise to be realistic
5. Manned threats were not challenging or credible
6. Computer-controlled threats were too proficient

Despite these shortcomings, the simulator training overall was considered to be a tremendously valuable training tool, providing much needed training not available by other means. While these utility studies provide some insight into the value of air-to-air simulator training, they do not address whether a pilot's performance actually improved due to that training. In-simulator learning studies accomplish this by measuring performance improvements taking place "as a function of practice within the simulation."[16]

In-Simulator Learning (ISL) Studies

1981 SAAC ISL Study

The earliest ISL study was conducted in 1981 by the USAF Tactical Fighter Weapons Center at Nellis AFB, Nevada. This study used the SAAC to demonstrate performance improvements in the simulator flying BFM and ACM against a constructive threat. The study "reported significant improvements in weapons employment ... [including] quicker first shots ... more valid shots, and fewer missed shot opportunities."[17]

F-14 ACMS ISL Study

The next year a Navy study demonstrated ISL in the F-14 Air Combat Maneuvering Simulator (ACMS) at Oceana NAS, Virginia. The ACMS combined two 40-foot domes similar to the MACAIR simulators, but could only project a single threat image, restricting it to BFM or

ACM. The threat could be controlled by computer, console-operator, or from the other dome simulator.

The study measured aircrew performance using an All-Aspect Maneuvering Index (AAMI) proving an overall score "based upon a formula that incorporates range, antenna-train-angle, and angle-off-the-tail as the major variables"[18] A higher AAMI score indicated a more offensive position at the conclusion of each engagement. The test involved experienced F-14 aircrew flying BFM against a computer-controlled threat. Three engagements were used as a pre-test prior to receiving 40 training engagements. An identical test was given following the training, resulting in scores "much higher than pre-test scores, [indicating] that the training ... in the simulator does, in fact, improve performance."[19]

1990 SAAC ISL Study

In 1990 a second SAAC ISL study "also demonstrated significant improvements in performance as a function of simulator training ... using the AAMI as the primary measure of performance."[20]

MACAIR ISL Study

The MACAIR facility was also used to conduct ISL studies. The multiple-threat capability of this facility allowed Armstrong Laboratory to study offensive and defensive counter-air (OCA & DCA) missions. F-15 pilots were paired into 16 elements for three days of "intense simulation training."[21] Controlled scenarios were flown before and after the training, revealing "significantly higher" performance after training.[22] Measures used for the comparison included

F-15 survival, mission success (e.g. percentage of adversary bombers destroyed prior to reaching their target in DCA missions), and mission efficiency (weighted exchange ratios), as depicted in figure 1.

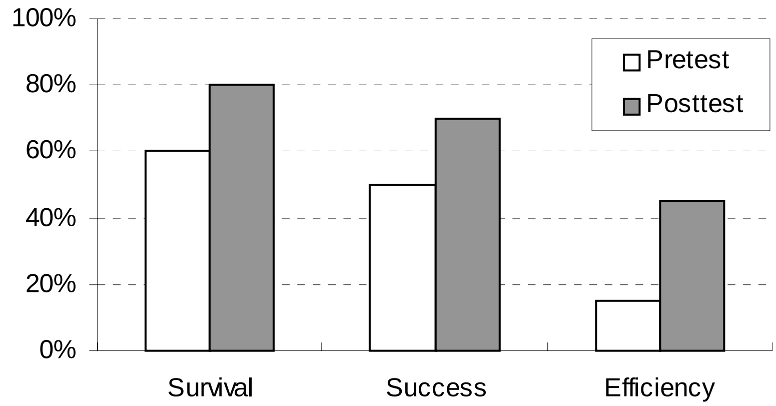

Figure 1. DCA Pre/Post Test Performance Comparison23

1993 MULTIRAD ISL Study

Armstrong Laboratory conducted another ISL study starting in 1993 using their own multiship simulation facility (MULTIRAD) at Williams AFB (now Williams Gateway Airport) in Mesa, Arizona. This facility combined two high fidelity F-15 cockpits (360-degree visual) with two F-16 (adversary) cockpits and a WD station.[24] Numerous constructive friendly and threat aircraft were added to the scenarios. As part of a larger program researching situational awareness (SA), this study examined, among other things, "the potential of multiship simulation as a tool for training SA."[25] To measure performance, an SA rating scale (SARS) was developed to identify 24 "behavioral indicators" of a pilot's SA (table 2). SA was defined as "a pilot's

Table 2. Categories and Indicators used in SARS

Category	Behavioral Indicators
Tactical Game Plan	Developing plan Executing plan Adjusting plan on-the-fly
System Operation	Radar Tactical electronic warfare system Overall weapons system proficiency
Communication	Quality (brevity, accuracy, timeliness) Ability to use controller information
Information Interpretation	Interpreting vertical situation display Interpreting threat warning system Ability to use controller information Integrating overall information Radar sorting Analyzing engagement geometry Threat prioritization
Tactical Employment-BVR	Targeting decisions Fire-point selection
Tactical Employment-Visual	Maintain track of bogeys/friendlies Threat evaluation Weapons employment
Tactical Employment-General	Assessing offensiveness/defensiveness Lookout Defensive reaction Mutual support

Source: Adapted from Wayne L. Waag et al, "Use of Multiship Simulation as a Tool for Measuring and Training Situation Awareness," in AGARD-CP-575, *Situation Awareness: Limitations and Enhancement in the Aviation Environment*, (Neuilly-Sur-Seine, France: Advisory Group for Aerospace Research and Development, January 1996), table 1, 20-2.

continuous perception of self and aircraft in relation to the dynamic environment of flight, threats, and mission, and the ability to forecast, then execute tasks based on that perception."[26]

Forty MR F-15 flight leads (study subjects) and 23 wingmen flew 36 engagements, progressing incrementally in complexity. Subject matter experts (SME) observed each engagement and rated subject pilots on each of the 24 behavioral indicators. Each Indicator was graded on a six-point scale from 1-“Acceptable” to 6-“Outstanding.”[27] An SA score was then derived using SA Rating Scales (SARS).[28] A comparison of two missions flown the first and last day indicated a statistically significant improvement in 2v2 DCA missions, but only a small (not statistically significant) improvement in 2v4 OCA missions (figure 2).

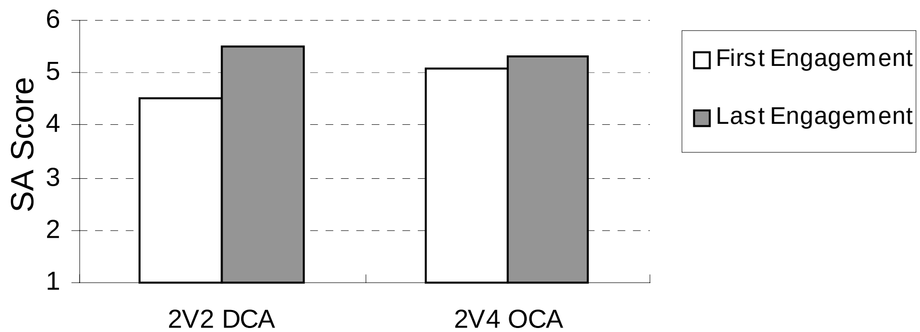

Figure 2. Effects of Practice on Observer SA Ratings[29]

Because each mission increased in complexity, the trend was actually a decrease in SA scores as the study progressed. However, after weighting the scores for all scenarios according to difficulty (determined by the SMEs), the seven simulator sorties were shown to progressively improve SA (figure 3).

Armstrong Laboratory surveyed the pilots for information similar to the 1990 utility study. All pilots rated the training to be beneficial, but training was rated more beneficial for pilots upgrading to a higher qualification level, such as a wingman in Mission Qualification Training

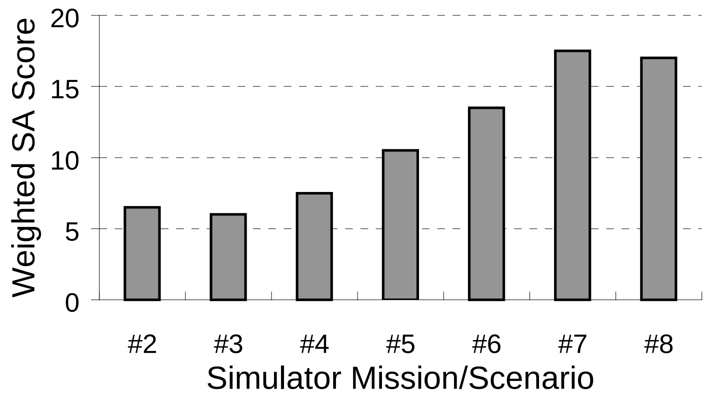

Figure 3. SA Scores Weighted for Scenario Difficulty Across Missions[30]

(MQT) or upgrading to two-ship flight lead, or a two-ship flight lead upgrading to four-ship lead (figure 4).

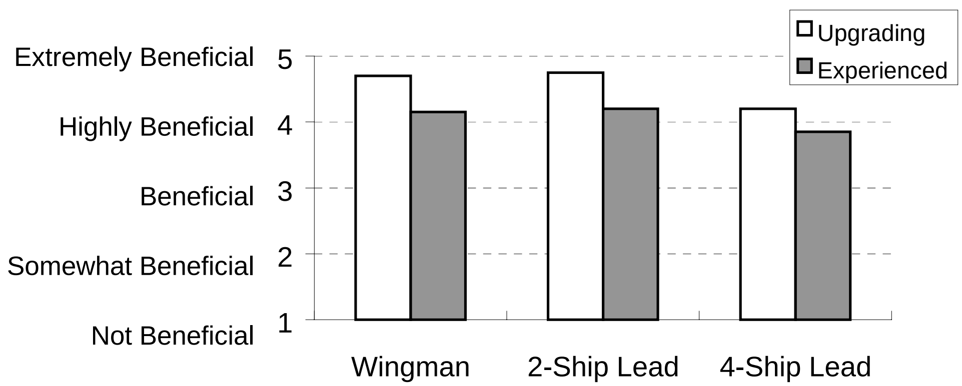

Figure 4. Rated Benefit of Training for Various Levels of Experience[31]

ISL studies to date suggest learning is taking place in air-to-air simulator training, and is further supported by survey data, but success within a given simulator environment does not necessarily mean learning in the simulator will improve task performance in flight. Simulator learning must also improve performance in the aircraft.[32]

Transfer of Training (TOT) Studies

Transfer of training (TOT) studies measure performance improvements in flight due to simulator training. Sometimes referred to as "transfer of learning,"[33] these studies show simulator training (or learning) influencing later behavior in an aircraft. Ideally this influence will reinforce desired behavior, but it can also create undesired habits or behavior—negative training transfer.[34]

Control Groups

TOT studies generally involve two groups: an experimental group and a control group. The experimental group receives simulator pre-training before being tested or trained further in an aircraft, while the control group begins aircraft testing or training without simulator influence. The resulting performance difference between the two groups indicates whether the simulator influence was positive or negative for that training.

The control groups do not replace missing simulator training with flight training; in fact, the control group is expected not to receive any additional flight training during the time the experimental group is accomplishing simulator sorties. If the control group *is* given any flight training, the same flight training should also be given to the experimental group to ensure the only variable between the groups is *simulator* training.[35]

The nature of TOT studies is to demonstrate that tasks learned or improved in a simulator can be applied to actual flight. TOT studies *do not compare simulator training to flight training*; they make no attempt to prove that simulation is *better* than in-flight training. However, one *implication* of positive transfer is that "use of the simulator can reduce dependence upon operational aircraft during training by influencing the learning of tasks that must be performed in those aircraft."[36] In other words, if simulator training results in more efficient flight training, fewer flights should be required to achieve the same objectives (or, the same number of flights can be used to reach higher objectives).

1975 Navy TOT Study

The first simulator-to-flight TOT study on air combat training was conducted in 1975 with Navy F-4J students. This was the first simulator to use a remotely controlled adversary. The experimental group practiced eight BFM maneuvers against a single adversary during six simulator sorties. Instructors graded pilot performance of each maneuver using 12 "performance variable" (PV) criteria on a scale of zero-"F" to 12-"A+." Instructors also indicated one of five possible final positions obtained at the end of each engagement: firing position, lag pursuit position, offensive, neutral, or defensive.[37]

After training the experimental group on all simulator events, both experimental and control groups flew six BFM sorties for aircraft training in the same maneuvers—again graded on PVs and final positions for each maneuver. Overall, "the experimental group achieved a more advantageous average position, came to an AIM-9 final position more often, and required fewer maneuvers to achieve firing positions than did the control group."[38] In-flight grades for the experimental group averaged higher for each of the sorties flown as well as for each maneuver, although the differences were slight (figure 5).

Although the experimental group averaged better grades in all maneuvers, only the rolling scissors maneuver demonstrated a statistically reliable difference. One postulated cause for the slight differences in the remaining maneuvers was a lack of control during in-flight sorties, such as variations in the number, order, and types of maneuvers flown during each syllabus mission. It was also postulated that transfer results would have been higher if not "diluted" by a long time delay between simulator training and subsequent flight training. Third, it was believed that sequencing each flight to follow its corresponding simulator event would have yielded better results.

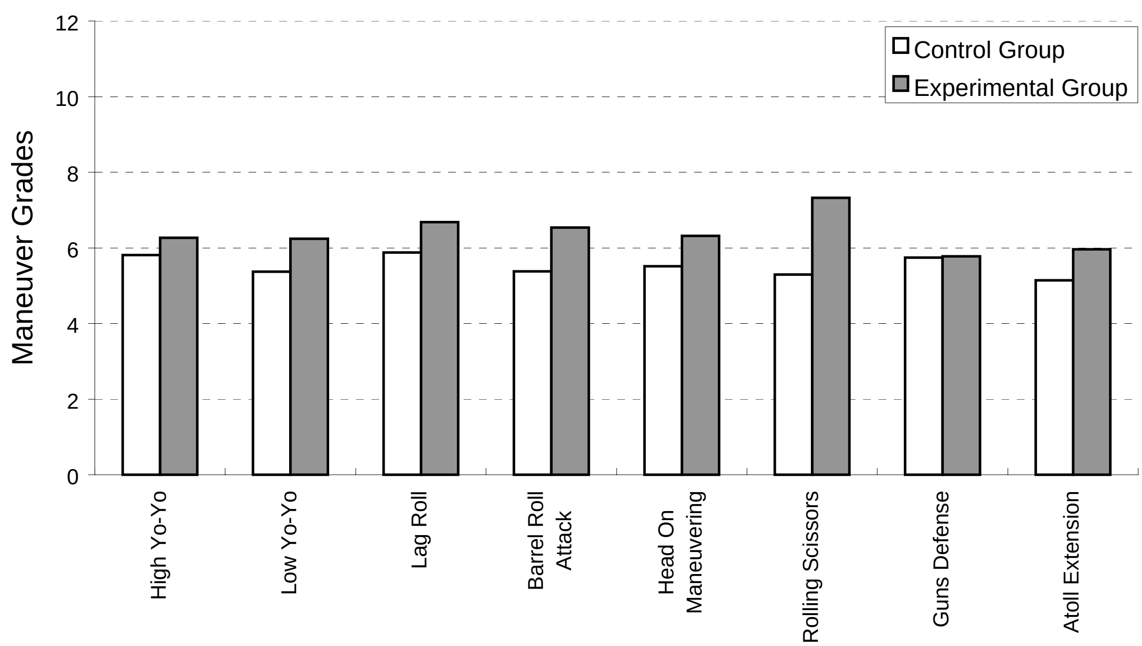

Figure 5. BFM Maneuver Grades[39]

Although the rolling scissors maneuver was considered to be most difficult, it achieved the highest transfer—a 38% improvement in grades between experimental and control groups. In addition, rolling scissors maneuvers were most hampered in simulation by a limited visual display, making its high transfer even more remarkable. Although an isolated demonstration, "food for thought" was offered: "transfer effects may be augmented when the pretraining task (simulator pretraining) is somewhat more difficult than the ultimate task (aircraft retraining)."[40] It was also suggested that simulator fidelity is less important than *how* the simulator is utilized. "Transfer of learning seems likely more a function of goodness of *instruction* than a fidelity of simulation ... [involving] use of the powerful technique of training for transfer: training 'around' (or in spite of) limitations that are ... inherent in the simulator." (Emphasis in original)[41]

Individual performance variables were also analyzed to determine if there were significant grade differences between groups. Taking PV grades for all maneuvers into consideration, only one variable, "nose position at pull down," demonstrated a statistically reliable difference; none-the-less, *all* twelve PVs were rated better for the simulator-trained group (figure 6). "This consistent superiority can not be ignored."[42]

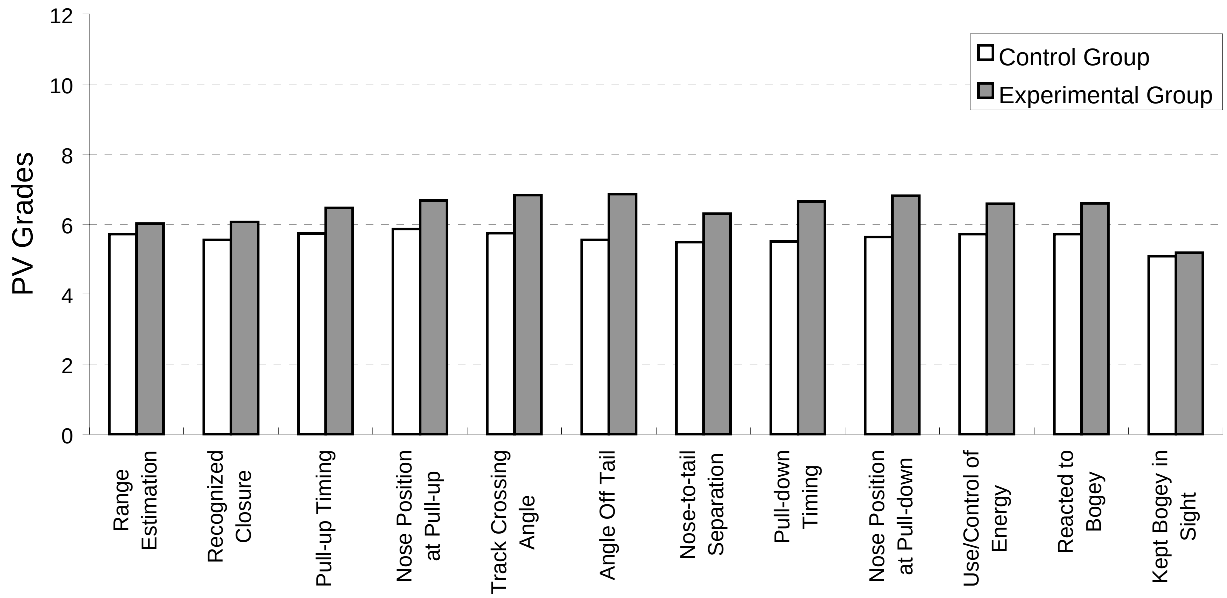

Figure 6. BFM Performance Variable Grades[43]

By isolating PV grades for each BFM maneuver, two PVs were found responsible for distinguishing the rolling scissors maneuver above the rest. These were two PVs "instructors considered most important: Use/Control of Energy and Nose to Tail Separation. The superiority of the experimental group in the rolling scissors was, then, achieved by enhancing performance on important variables."[44]

The study also hoped to determine the number of aircraft training hours that could be replaced by an hour of simulator training by "proficiency advancing" or skipping some aircraft time for experimental group pilots, but was unable to do so because "the study was simply too short."[45]

1977 SAAC TOT Study

Air Force Human Resources Laboratory (AFHRL) utilized SAAC F-4 simulators for a TOT study in 1977, conducted primarily as a platform motion study. Student pilots were placed into three groups: six were given no simulator training, eight were given simulator training with motion, and eight more were given simulator training without motion. IPs graded each student's performance of nine "skills" and ten BFM "tasks" on a scale of zero to nine. (Skills and tasks were similar to the PVs and maneuvers used in the 1975 Navy TOT study.) [46]

Some in-simulator learning was demonstrated (although not statistically reliable) by comparing performance measures of the first and last simulator sorties. AFHRL was unable to measure in-*flight* learning due to a limited number of available sorties—each sortie increased in difficulty, with no spare sorties to repeat the first profile for a pre/post test comparison. Of primary interest, comparing in-flight performance between the control group and the two simulator-trained groups *failed* to demonstrate an effective transfer of training: "The data indicated that the SAAC training did not seem to increase instructor ratings of performance in the aircraft."[47]

AFHRL considered the small transfer effects to be a trend in BFM simulator TOT studies, meaning they were not very successful at finding variations in performance. It referenced the 1975 Navy TOT study (above) and an additional study conducted during SAAC FOT&E student training (without reference or dates), where "a comparison of instructor ratings from BFM training yielded ... a very small positive effect."[48] A lack of objective measures was also offered as explanation for the failure to demonstrate significant transfer. Task and skill scores were based purely on the subjective judgement of the same IP giving instruction from the adversary simulator cockpit; instructor ratings may not have been "sufficiently sensitive [or] reliable."[49]

Additional causes for transfer failure were postulated, including the possibility of an ineffective simulator training *approach:*

> The reader should keep in mind the integral relationship of training program and training device. Training effectiveness is a function of both of these. Even though significant training effectiveness was not demonstrated under the conditions of the current study, this does not mean that all SAAC training will be noneffective. It only means that the right training program and training device capability combination was not demonstrated in this study.[50]

Instructors "were reluctant to use SAAC much differently than they might employ an aircraft, that is, they tended to ignore many of the unique instructional features of the SAAC."[51] For example, instructors did not use the simulator freeze or reset capability to identify and fix errors as they occurred; instead, errors were allowed to compound.

1980 SAAC TOT Study

Another SAAC TOT study was conducted during an F-4E Fighter Weapons Instructor Course (FWIC) in 1980. This time more objective measures were used, and successful transfer was observed during BFM and ACM simulator training. "SAAC-trained pilots had significantly more valid missile and gun shots. They also achieved higher exchange ratios and achieved a higher class standing in the course."[52] The results were statistically "significant," but barely so; the differences in performance between the simulator-trained group and the control group were still relatively small.[53]

Unfortunately, no air-to-air combat simulator TOT studies have been documented since 1980. This represents a break of almost 20 years, with no TOT studies of multi-ship simulation.

Summary of Simulator Study Findings

Although in some cases the results were only slight, overall the utility, ISL, and TOT studies provide confidence that air-to-air simulator training can be effective. Review of these studies uncovered several findings that may be applicable to modern simulation training such as DMT. These include some insight into the benefits and limitations of air combat simulation training, as well as offering techniques to improve programs to maximize their training potential. The next chapter will discuss the implications of these findings for improving F-15C air combat training with DMT.

Notes

[1] Herbert H. Bell and Wayne L. Waag, "Evaluating the Effectiveness of Flight Simulators for Training Combat Skills: A Review," *The International Journal of Aviation Psychology* 8, no. 3 (1998): 225-226.

[2] Lawrence D. Pohlmann and John C. Reed, *Air-to-Air Combat Skills: Contribution of Platform Motion to Initial Training*, report no. AFHRL-TR-78-53/AD A062738 (Williams Air Force Base, Ariz.: Air Force Human Resources Laboratory, Operations Training Division, October 1978), 7.

[3] Ibid., 14.

[4] Bell and Waag, 229.

[5] Wayne L. Waag and Herbert H. Bell, *Estimating the Training Effectiveness of Interactive Air Combat Simulation*, report no. AL/HR-TP-1996-039 (Mesa, Ariz.: Armstrong Laboratory, Human Resources Directorate, February 1977), 2.

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[20] Bell and Waag, 229.

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[24] Wayne L. Waag et al., "Use of Multiship Simulation as a Tool for Measuring and Training Situation Awareness," in AGARD-CP-575, *Situation Awareness: Limitations and Enhancement in the Aviation Environment* (Neuilly-Sur-Seine, France: Advisory Group for Aerospace Research and Development, January 1996), 20-3.

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[30] Ibid., adapted from figure 6.

[31] Ibid., 20-5, adapted from figure 4.

[32] Paul W. Caro, *Some Factors Influencing Air Force Simulator Training Effectiveness*, report no. HumRRO-TR-77-2 (Alexandria, Va.: Human Resources Research Organization, March 1977), 21.

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[34] Hawkins, 191.

[35] Caro, 13.

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[40] Ibid., 56-57.

[41] Ibid., 57.

[42] Ibid., 40.

[43] Ibid., 42, adapted from figure 12.

[44] Ibid., 52.

[45] Ibid., 55.

[46] Pohlmann and Reed.

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Chapter 3

Implications for DMT

> *We're going to have to prove to them that it works, and the measure of merit will be when those F-15 crews come out of those simulators in 1999, sweating and with smiles on their faces. That will happen because they will have gotten high quality training ... they simply can't get anywhere else.*
>
> —General Richard E. Hawley

Training effectiveness studies provide some insight for improving air combat simulator training. Findings demonstrated simulator training was effective, while highlighting some of the limitations and unique benefits of such training and offering some techniques to improve simulator training programs. These findings provide insight on how to better prepare F-15C pilots for air combat through Distributed Mission Training.

Of the ten simulator studies reviewed, all but one at least confirmed air combat simulation training is effective, contributing to pilot learning and improving performance. The single study not showing positive learning was at worst neutral, so it does not necessarily belie the value of simulator training—it simply did not find a measurable difference in pilot flight performance due to simulator training. The MULTIRAD ISL study and most of the TOT studies demonstrated only small positive effects. This may highlight limitations of the metrics used, the training devices, the training programs, or all of the above. The question of training *device* could have been resolved if training accomplished in flight was shown to improve performance while simulator training did not, but no such comparisons were made.

None of the results compared simulator training to in-flight training. Although the MACAIR utility study used pilot surveys to identify tasks *perceived* as better trained in the simulator, there were no measured performance differences between simulator and in-flight training. The Navy TOT study was the only study even suggesting such a comparison, but it was unable to actually measure a demonstrable difference in flight performance.

There were, none-the-less, many lessons learned that can be applied to DMT programs. Some of the results presented were nothing more than conjecture, but should at least be considered for DMT program development. Unfortunately, most of the studies were not successive or collective, so none of the results led to deeper investigation. Although findings do not provide startlingly new evidence for simulator training application, they do highlight several concepts that should be applied in DMT programs to maximize training effectiveness.

Unique Benefits of Simulation

The MACAIR utility study surveys revealed several important advantages of simulation training over in-flight training. These included instruction options unique to simulator training, the ability to repeatedly practice desired training scenarios, and the opportunity to train in dangerous and complex mission scenarios with real-time kill removal.

Instruction Options

DMT offers several instruction options not possible in flight training. These options can easily be ignored as pilots default to their usual flight instructional techniques. The 1977 SAAC TOT study found instructors "were reluctant to use [simulators] much differently than they might employ an aircraft, that is, they tended to ignore many of the unique instructional features of the [simulator]."[1]

During flight training, resetting an engagement expends valuable time and fuel, and instructors must wait until after the debrief to provide detailed feedback. In addition, pilots must wait for another sortie to fix their errors. Distributed Mission Training, on the other hand, will allow instructors to "coach" players during air combat scenarios—an instructor can observe performance, freeze the mission, provide guidance, then either resume or reset the scenario. This will also allow other "extrinsic feedback," such as "cueing" (preparing a trainee to look for rare events or signals typically ignored just before they are presented), and "prompting" (presenting the correct response immediately after a stimulus or event occurs).[2] If desired, freeze, reset, and replay features are also selectable from the simulator cockpits.[3] This unique DMT capability should not be overlooked.

DMT scenarios can also be digitally recorded and saved for later playback in simulator cockpits. F-15C Flying Training Unit (FTU) instructors at Tyndall AFB are using this feature with their simulators to introduce student pilots to various sight pictures and situations, like a 360-degree Omni-Max theater.[4] Operational units should also consider using this capability to instruct more advanced tactical situations in DMT. This could be used, for example, to help pilots distinguish between various AIM-9M tones while tracking a target with flares, or teach pilots to visually recognize whether a missile in flight has failed or is tracking a target (i.e. with appropriate lead during intercept). After all, "a picture is worth a thousand words (flights).... Visual pictures provide the best learning tool for comprehension, retention and reinforcement."[5]

Finally, DMT will provide extremely detailed debriefing capabilities not available in flight training. Each mission will be digitally recorded and can be replayed on large screens, showing a "God's eye" view of the entire mission, similar to Air Combat Maneuvering Instrumentation (ACMI). Cockpit views will also be available and can include selectable overlays of aircraft radar, HUD, and Tactical Electronic Warfare System (TEWS) displays. These are but a few of many options available to accurately recreate and analyze each mission.[6]

Practice

Another unique training benefit of simulation is the opportunity to practice. Simulators not only provide pilots with additional "flight time," but they can also isolate specific tasks for repeated exposure, allowing pilots to practice skills in need of focused training. Practicing achieves "overlearning," which improves the chances of retaining task skills and habits, and "makes performance of the task more resistant to stress."[7] Practice and overlearning can become dangerous, however, if they develop undesirable "side-effects" or habits (negative training). After all, "practice does not make perfect, practice makes permanent."[8]

Distributed Mission Training will, for the first time, provide operational F-15C units with the capability to isolate and repeatedly practice *team* skills. Before DMT, F-15C simulator training was limited to single-ship operations that could cause negative training by not allowing pilots to develop team habits required in actual flight. Practicing targeting in an isolated simulator, for example, can build a single-ship mindset and a habit of "heads down" operation, ignoring important communication and visual lookout requirements during this crucial phase of an intercept.[9] With DMT, pilots can practice as they would in flight—as a team. This will also provide flight leads with more exposure to decision-making opportunities.

Complex Mission Scenarios

Pilots surveyed during the MACAIR utility evaluations considered mission scenarios to be the "key ingredient to the training value" of multiship simulator training.[10] Similarly, DMT scenarios can be customized, allowing pilots to practice a wide variety of missions. Real-world airborne and surface-to-air threats will be selectable to provide realistic dissimilar air combat training (DACT) not readily available in flight training.[11]

Rigorous DMT scenarios can prepare pilots for complex training exercises such as Red Flag or Cope Thunder. This was demonstrated in a distributed mission simulation study involving A-10 aircraft conducting close air support (CAS) missions. Practicing a Red Flag scenario in distributed simulators "did well to prepare young wingmen for their first real Red Flag," dealing with the complicated communications and timing for multiple aircraft strikes.[12] Even more importantly, DMT complex training should prepare pilots for actual combat.

DMT offers another unique feature of combat not possible in flight training: real-time kill removal. The MACAIR utility evaluations identified this as "an especially important advantage of simulator-based training."[13] This capability is particularly helpful against multiple threats, allowing untargeted threats to be sorted after killed threats disappear. In addition, "killed" F-15C pilots will receive immediate performance feedback from poorly executed tactics when their simulator ceases to function, indicating their death.

High-risk tasks can also be practiced in the DMT environment without jeopardizing pilot safety. A typical example is practicing emergency procedures; but with DMT, realistic visual displays can include dangerous tactics such as low-altitude defensive maneuvers against SAMs or artillery. However, pilots should be aware that lacking "fear of demise" might build habits of performing maneuvers unsafe to accomplish in actual flight.[14]

Training Device Limitations

Sources of Negative Training

Because simulators cannot duplicate every aspect of flight, pilots have long been concerned with negative training. Pilots have often been required to put up with various unrealistic aspects of simulation, commonly referred to as "sim-isms." "Many examples of negative training have been demonstrated in flight simulator work.... It is very important to be able to identify elements of training which can lead to negative transfer."[15] An evaluation of negative training sources identified in previous studies may highlight negative factors possibly affecting DMT. Once potential sources of negative training are identified, the challenge remains to determine how to minimize their effects.

Surprisingly, the MACAIR utility study was the only one to address potential sources of negative training. A majority of the problems identified were concerned with specific hardware and software limitations of the MACAIR facility. Problems included target projection colors and resolution, cockpit hardware differing from F-15C aircraft, unrealistic WD information, and unrealistic air threats. Fortunately, F-15C MTC simulators are expected to be much more sophisticated than the 1990 MACAIR simulators—cockpit hardware, visual fidelity, WD stations, and threats should be much more realistic.

Pilots in the MACAIR utility study were confused by target aircraft color changes, and complained "that aircraft attitude, aspect angle, and tactical range could not be identified within distances typical in the air ... [interfering] with tactical formation, visual mutual support, BFM, and ACM/ACT."[16] The F-15C MTC cockpit high resolution Target Projection System (TPS) will project a single "monochrome green" color to represent target images. It will "provide sufficient resolution to determine target aspect and rate changes of an F-15 sized aircraft up to 12,000 feet"[17] allowing normal formation-keeping. It will display up to seven targets in high resolution from a realistic tally range of ten nautical miles to as close as 300 feet.[18] These capabilities should prevent target projection problems identified in the MACAIR study.

Pilots also found problems adapting to a modified F-15E cockpit. F-15C MTCs will prevent hardware mismatches by ensuring all simulator cockpits are fitted with current aircraft hardware and software. By contract "the system will be kept current with the F-15C to include all Operational Flight Programs (OFP) and any and all modifications scheduled for inclusion into the aircraft."[19] Upgrades will be incorporated "within the 60 day period preceding the operational use of modified or upgraded home station aircraft."[20]

Unrealistic WD information was previously eliminated by MACAIR after their utility evaluation by incorporating a more realistic WD station.[21] MTC weapons director stations should also be acceptable, designed “to allow a controller to provide *realistic* radar control to the scenario.” (Emphasis added)[22]

Also mentioned was pilot dissatisfaction with constructive and interactive threat behavior. Constructive threats seemed to operate beyond the maneuvering or weapons capabilities of actual threats, with superb capability. The MTC combat environment, will “accurately model physical, electronic, and aerodynamic capabilities of real world threats including ... flight and maneuvering performance ... sensors ... on-board weapons ... evasive maneuvers,” and other threat specific capabilities. Threats will also “emulate real world tactics and doctrine based upon ... the identified experience level of the crew.”[23] This will allow pilots to select scenario difficulty by choosing the performance capability of their opponents.

Manned interactive threats, controlled by F-15 pilots from an adversary cockpit, “did not provide a challenging or credible threat.”[24] This was partially due to F-15 pilots’ lack of proficiency using adversary cockpit displays and controls. MTC threat cockpits will also be unique—controls and displays will not resemble those in the F-15. Having F-15 pilots fly as Red Air in these cockpits could not only reduce threat credibility for training Blue Air pilots, but could also cause negative training for pilots operating the unfamiliar devices. As an alternative, any of the four F-15 simulators could be used to replicate threats.

Fortunately, F-15 pilots are not expected to operate MTC interactive threat cockpits. The MTC concept of operations calls for contractor instructors to operate threat stations rather than other F-15C pilots.[25] This concept is encouraging, since it should also reduce requirements for

F-15 pilots to fly adversary tactics (which could arguably be another source of negative training for F-15 pilots).

While MTC design specifications seem to rule out identified sources of negative training in past simulator facilities, a test of the working system will be required for confirmation. When the first F-15C MTC becomes functional this spring, a simulator certification (SIMCERT) process will utilize aircrew expertise to ensure its simulators "are physically and functionally maintained to the design configuration and provide accurate and credible aircrew training.... Concurrently, SIMCERT [will identify] potential negative training due to inaccurate simulation of aircraft systems or performance characteristics."[26] Hopefully MTCs will meet or exceed all design specifications. (Other planned MTC evaluations are discussed in appendix C.)

Physiological Considerations

Conspicuously absent from identified sources of negative training is the inability to simulate physiological factors present in flight.[27] Simulator studies investigating physiological issues do exist, but none were found addressing implications for air combat training. Although the 1977 SAAC TOT study did attempt to measure affects of simulator motion, the results were inconclusive, neither supporting nor discouraging use of simulator motion.

Flying exposes aircrew to other stresses not possible to simulate: physiological stress such as Gs, altitude, and stress from the realization that a mistake in flight can cause loss of life. Pilots must get enough in-flight training to acclimatize themselves to these stresses, to build good anti-G straining maneuver (AGSM) habits and techniques, [28] to learn aircraft handling characteristics and "feel," and to make tough decisions in real-life scenarios. How much and how often pilots need to "shake and bake" to be acclimatized remains uncertain.[29]

Training Programs

Knowledge of the intrinsic benefits and limitations of DMT can serve as the basis for developing an effective training program. The most obvious example is the need to develop programs avoiding or reducing the effects of negative training when they are unavoidable.

Reducing the Effects of Negative Training

Even if DMT simulation does not perfectly reflect reality, this should not prevent a well-designed training program from being effective. Simulator fidelity is often inappropriately blamed for training ineffectiveness—doing so "ignores the manner in which a device is used and the objectives of device training. These two considerations underlie any determination of simulator training effectiveness."[30]

The underlying objective of each task or training event needs to be considered for determining the appropriateness of accomplishing that training in either flight or with DMT. There is a "need for a proper task analysis and an understanding of the learning processes associated with achieving a satisfactory performance of the task, before determining the nature of the training equipment to be employed."[31] To use a controversial example, if the BFM objective is to learn energy management by honing pilot sensitivity to aircraft Gs and buffet cues, this objective must be accomplished in flight. On the other hand, if BFM objectives are to recognize threat energy state based on visual cues such as closure and line-of-sight rate, DMT can be very useful—the picture can even be frozen or replayed for emphasis.

Training events are actually more complex than this and often cannot be isolated to a single objective or single "cue." Still, flight leads and instructors can exploit the capabilities of each device (simulator or aircraft) by emphasizing cues the training device is most capable of accentuating. Combining both devices will provide the best opportunity to satisfy most training objectives. Using another BFM example, "demonstrating the effects of increased turn rates without the high-Gs in the simulator may enhance the pilot's conceptual understanding to be applied to the mission the next day."[32]

For those aspects of flight DMT cannot simulate, the potential for negative training is unavoidable. However, it may be possible to reduce the risk of negative training through proper instruction. The 1975 Navy TOT study mentioned the "powerful technique of ... training 'around' (or in spite of) limitations that are inherent in the simulator."[33] This concept is also described in an AFHRL guide for conducting TOT studies: "Studies showed that, if the problem is made quite clear to the student prior to and during simulator work and prior to and during airborne work, such training *for* transfer completely offsets the potential [of negative transfer], the student having little difficulty in either the simulator or the aircraft." (Emphasis in original)[34] In other words, simply reminding pilots of what the actual environment entails can reduce the effects of negative training. If the potential for negative transfer is high, more frequent reminders may be required to ensure pilots maintain a realistic mindset.

> This procedure need not be paradoxical because, frequently, different pilots make use of different sets of cues as aids during performance of the same maneuver; these perhaps depending on their individual preferences. Even the same pilot may use different sets of cues at different times.... The pilot makes do with alternatives that serve the same purpose.[35]

In addition to identifying sources of negative training and reducing their effects, air combat simulation studies provide additional insight for improving simulator training programs. Findings suggest how to exploit DMT's unique training capabilities by identifying what tasks should be emphasized in DMT, who will gain the most training benefit from DMT, and when to schedule DMT events to optimize training.

Tasks to Emphasize in DMT

The most obvious tasks to emphasize in DMT are those tasks or missions incapable of being trained in flight, such as the dangerous tasks or complex missions—DMT provides a unique benefit for this training. More generally, DMT should focus on continuation training (CT) shortfalls—tasks needing more attention than is provided in flight training.

MACAIR utility evaluations provide a list of combat tasks considered best trained in the simulator, correlating with tasks in need of additional training (table 1). Although this specific list is likely outdated, it demonstrates the concept of focusing DMT on CT shortfalls. These shortfalls may vary each year, and may even vary by unit, since training opportunities and restrictions differ for each wing. The ACC commander also envisioned DMT as a tool to compensate for CT shortfalls. General Hawley recognizes air combat training becoming increasingly constrained due to shrinking budgets, airspace limitations, concern for safety, and operational tasks limiting training opportunities.[36]

Even if some tasks or mission segments are not initially viewed as shortfalls because they are included in CT, they may still require extra attention simply because in-flight training does not provide sufficient time to reach a desired level of proficiency. For example, only *seconds* of training are provided during an entire flight for conducting threat identification in accordance with established ROE and employing weapons. DMT will allow teams to quickly reset and repeat any mission, mission segment, or task to gain "psychomotor" time exercising desired skills to become proficient as a team.[37]

Difficult tasks may be identified as CT shortfalls because they require more training to master. Simulation allows focused exposure to difficult tasks, so it can serve as an outstanding tool to improve performance. The 1975 Navy TOT study even suggested training transfer is enhanced when a *training* task is more difficult than the *actual* task.[38] For DMT this simply means training should be as challenging, if not more challenging, than actual flight (or actual combat). This is supported by pilots surveyed in the MACAIR utility study, who thought the "challenging, demanding, [and] realistic" scenarios were "the key ingredient to the training value" of multiship simulation.[39] "Perishable skills" will also *seem* difficult if proficiency is allowed to atrophy. DMT can provide pilots with multiple exposure to skills to regain proficiency or currency in a "safe" environment.

Improving Training with Metrics

Units can identify major CT shortfalls intuitively or by survey. The MACAIR utility evaluations found remarkable consistency in tasks needing additional training. However, using *performance* measures to identify shortfalls may prove more useful in highlighting less obvious tasks needing focused training. The same metrics can provide definitive data for identifying trends, and provide feedback to ensure both in-flight training and DMT programs improve performance.

The ISL and TOT studies offer several measurement methods. Many of the studies used "outcome" measures, identifying only the final result of an engagement. Outcome measures may be useful for evaluations or competitions, but are not useful for determining what caused that outcome. "Process" measures, on the other hand, can identify causal effects. This can be extremely useful for determining what training aspects need emphasis.[40] The 1975 Navy TOT study attempted to measure how mission outcomes were achieved using performance variables (PV). Their analysis identified two PVs most responsible for improving rolling scissors maneuvers: "Use/Control of Energy, and Nose to Tail Separation."[41]

The 1977 SAAC TOT study "skills" and the 1993 MULTIRAD study SA "behavioral indicators" (table 2) are also examples of process measures. They look remarkably similar to common grade sheets—breaking down missions or engagements into discrete tasks leading to success. Unfortunately, neither of these studies analyzed their data to determine how the processes contributed to each mission as the Navy TOT study did; process measures were used only to derive an overall performance score for each engagement.

For both outcome and process measures of performance, *subjective* ratings often did not produce significant variance to measure trends, such as the instructor ratings used in the 1977 SAAC TOT study.[42] Instructors tend to ignore extreme grades on scaled measurements, "because of operational practice calling for a majority of grades to cluster in the region of ‘average.’”[43] The 1975 Navy TOT study attempted to compensate for this practice by expanding their grading to a 12-point scale, but this still largely resulted in clustered grades—the rolling scissors being the only maneuver demonstrating a significant variance (figure 5). Objective measures used in the first three ISL studies and the 1980 SAAC TOT study were more successful in obtaining significant results, using AAMI or weapons employment data.

Future efforts to measure and compare both simulator and flight task performance could be useful for several purposes. First, it could identify tasks receiving a large training benefit from simulator training—DMT could then be used as a primary training tool for those tasks. Second, tasks receiving little training benefit could be directed to other training means (i.e. swap emphasis from DMT to flight or vice versa)—this would ultimately determine the proper mix of in-flight and DMT sorties needed to develop and maintain task proficiency at desired performance criterion. Third, noting changes in task performance by varying setups, scenarios, and instructor techniques can help identify methods for optimizing these variables to match desired objectives. Finally, the same task measures can be used to compare and track individual pilot abilities, identifying their specific training needs.

Performance measures—like statistics for baseball players—provide a record of players’ capabilities, provide trend information to monitor progress or regression, provide feedback to the players, stimulate competition, and identify individuals for awards.[44] Many F-15C squadrons already use some performance measures, such as weapons employment data, to determine monthly “Top Gun” award-winners. This data could be used to identify weapons employment skills needing extra training—training that can be emphasized in DMT. Top Gun competition could easily be expanded to include more than just weapons data. A simple example is tracking the percentage of times a pilot "targets" the correct group. Top Gun could also include DMT events to determine simulator training performance. This would provide a much larger representation of training engagements accomplished, and motivate pilots in the simulator.

Using objective performance measures to customize training can also reduce debates about the desired complexity of training profiles for pilots of varying flight qualifications, as was seen in the MACAIR utility study. Measuring performance would determine whether or not a profile is in fact too complex or "too demanding for a new wingman."[45]

Customize Training Profiles by Flight Qualification

Personalizing training for each individual pilot may be difficult, but possible using DMT with its flexible scenarios and setups. However, for planning purposes, operational units need to design training profiles in advance, from which modifications can be made for individuals.[46] Finding logical "audience" groups would be extremely useful to determine how to vary tasks and missions in "customized" profiles.

The 1993 MULTIRAD ISL study demonstrated air combat simulation was most beneficial for (or most appreciated by) upgrading pilots (figure 4). Also, new wingmen in the MACAIR utility study (who can be considered "upgrading" pilots) found training more valuables than did experienced pilots in several tasks.[47] This concept is not inconsistent with difficult or perishable skills requiring extra training, since upgrading pilots are likely to find new flight duties or tasks difficult due to their inexperience. DMT now offers the capability to expose upgrading or inexperienced flight leads to multiple "difficult" situations, allowing them to develop and exercise their new decision-making responsibilities.

Currently CT requirements vary according to pilot experience (total flight hours), as reflected in the Ready Aircrew Program (RAP). In determining how to vary MTC training profiles, it may be useful to further divide training plans by flight qualification, since required tasks change dramatically for each level (wingman, two-ship lead, four-ship lead, and IP). While refining the SA rating scales (SARS), an Armstrong Laboratory study discovered average pilot SA scores increased significantly with each increase in flight qualification, accounting for 68% of the variance (figure 7). This is profound, considering F-15 hours only accounted for 35% of the variance, and total flight hours only 15%.[48]

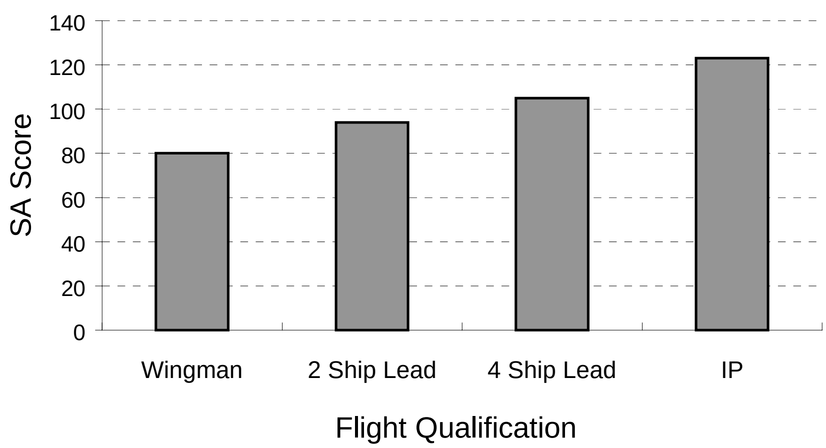

Figure 7. Composite SA Score as a Function of Flight Qualification[49]

After all, "pilots do not get the amount of practice at *each* skill level that would be required for them to achieve their full potential." (Emphasis in original)[50] While developing training plans for DMT (or even new RAP requirements), it may prove useful to search for training tasks needing emphasis at each flight qualification level.

Scheduling DMT Events

The 1975 Navy TOT studies postulated two "diluting effects" reduced the effectiveness of simulator training. One of the diluting effects was caused by mass training all simulator events before in-flight training began. Researchers believed sequencing in-flight events to immediately follow corresponding simulator events would improve training transfer. The second diluting effect was an excessive time delay between simulator training and in-flight training, essentially allowing pilots to "forget" what they learned, or lose proficiency. To avoid these diluting effects, DMT and flight missions with matching objectives should be paired and scheduled in sequence. This way DMT can prepare pilots for the subsequent flight by exercising skills or tasks needing practice.

The concept of pairing complimentary DMT and flight missions resembles formal training syllabuses, but seems much less typical of CT, which enjoys scheduling flexibility. None-the-less, if it is possible to do the same in CT, pairing the two training methods will theoretically enhance the effectiveness training. Doing so may also allow pilots to reduce briefing and debriefing times, saving valuable pilot duty hours and increasing time efficiency.

Once the AEF cycles begin, units returning from deployments may have to formalize CT to regain combat readiness. Training is minimal on deployments, so when units return much time is dedicated to regaining currencies and upgrade training, leaving less time to hone complex combat skills.[51] DMT has the potential to add efficiency to syllabuses by providing focused training and rapid, multiple exposure to skills needing emphasis. This would allow pilots to progress more quickly from fundamentals back to complex scenarios, both in the air and in DMT. Once multiple aircraft and weapons systems incorporate DMT, the final stage of training can concentrate on "spin-ups," combining AEF teams via their MTC networks to train together in complex scenarios, and conduct mission rehearsals in contingency location environments.[52]

Notes

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[18] Ibid.

[19] Air Combat Command, "Systems Requirement Document (SRD) for the CAF F-15A/C MSIP Four-ship Simulator System and Aerial Combat Enhanced Simulation (ACES) Center," 28 March 1997, 9.

[20] Air Combat Command, "F-15C Simulation Capability Requirements Document for the Combat Air Forces (CAF) F-15C Multi-Stage Improvement Program (MSIP) Four-ship Simulation," 2.

[21] Houck, Thomas, and Bell, 16.

[22] Contract, 30.

[23] Ibid., 26-27.

[24] Houck, Thomas, and Bell, 13.

[25] Air Combat Command, Operations and Training Branch (HQ ACC/DOTO), "Concept of Operations for F-15C Mission Training Centers," Working Draft, 29 September 1998, 12.

[26] 29th Training Systems Squadron, "Simulator Certification (SIMCERT) Master Plan," 1 July 1997

[27] Hawkins, 204.

[28] Air Force Pamphlet (AFPAM) 11-404, *G-Awareness for Aircrew*, 19 August 1994, 4-7.

[29] Dr. Herbert H. Bell, telephone conversation with author, 19 November 1998.

[30] Paul W. Caro, *Some Factors Influencing Air Force Simulator Training Effectiveness*, report no. HumRRO-TR-77-2 (Alexandria, Va.: Human Resources Research Organization, March 1977), 22.

[31] Hawkins, 205.

[32] Oakes, par. 5.2.4.

[33] Thomas A. Payne et al., *Experiments to Evaluate Advanced Flight Simulation in Air Combat Training: Vol. 1, Transfer of Learning Experiment*, (Huntsville, Ala.: Northrop Corporation, March 1976), 57.

[34] Thomas A. Payne, *Conducting Studies of Transfer of Learning: A Practical Guide*, report no. AFHRL-TR-81-25 (Williams Air Force Base, Ariz.: Air Force Human Resources Laboratory, Operations Training Division, January 1982), 19.

[35] Ibid., 20.

Notes

[36] Gen Richard E. Hawley, commander, Air Combat Command, address to the National Training Systems Association 19th Interservice/Industry Training Simulation and Education Conference, Orlando, Fla., 2 December 1997.

[37] Payne, 56.

[38] Payne et al., 56-57.

[39] Houck, Thomas, and Bell, 13.

[40] Herbert H. Bell and Wayne L. Waag, "Evaluating the Effectiveness of Flight Simulators for Training Combat Skills: A Review," *The International Journal of Aviation Psychology* 8, no. 3 (1998): 238.

[41] Payne et al., 52.

[42] Pohlmann and Reed, 12.

[43] Payne et al., 21.

[44] Elizabeth L. Martin, *Practice Makes Perfect*, report no. AFHRL-TP-84-32 (Williams Air Force Base, Ariz.: Air Force Human Resources Laboratory, Operations Training Division, October 1984), 4.

[45] Houck, Thomas, and Bell, 15.

[46] HQ ACC/DOTO, "Concept of Operations for F-15C Mission Training Centers," 21.

[47] Houck, Thomas, and Bell, 15.

[48] Wayne L. Waag and Michael R. Houck, "Tools for Assessing Situational Awareness in an Operational Fighter Environment," *Aviation Space and Environmental Medicine* 65, supplement 5, May 1994, A17-A18.

[49] Waag and Houck, A18, adapted from figure 1.

[50] Martin, i.

[51] US Air Force, "Evolving to an Expeditionary Aerospace Force," *Commanders' NOTAM 98-4*, 28 July 1998.

[52] Gen Richard E. Hawley, commander, Air Combat Command, keynote address at the Interservice/Industry Training, Simulation and Education Conference, Orlando, Fla., 1 December 1998.

Chapter 4

Improving Future Training

If DMT and its inherent value is appreciated quickly, then today's (current) and tomorrow's (future) warriors will step into potential battles with the great advantage of improved flying ability, reflexes and "seeing" the big picture while making their own luck along the way. DMT has a future and is destined to be the cornerstone of air and space dominance in the future.

—Michael R. Oakes

Summary

Distributed Mission Training can improve air combat training for F-15C pilots if smartly integrated into continuation training. A proper balance of simulation and flight training should exploit the unique benefits of each training method while avoiding or reducing their limitations. Previous simulator studies provided some insight into the benefits and limitations of air combat simulation training, as well as offering techniques to improve programs to maximize their training potential. Most of these findings are applicable to DMT, offering combat units a basis for developing their own training programs as they enter the DMT network.

Unique Benefits of DMT

Simulator training offers several benefits not available in flight training, including unique instruction options, the capability to repeatedly practice desired tasks or missions, and the opportunity to train in complex scenarios not readily available in flight. DMT will allow instructors to "coach" and provide extrinsic feedback such as cueing and prompting. Debriefing can be conducted "on the fly" using freeze, replay, and reset features, so pilots can immediately re-attempt mission challenges and correct their errors. DMT will also offer extremely accurate reconstruction of missions for debriefing purposes in a wide variety of formats rarely (if ever) available in flight training. Instructors can even introduce pilots to new concepts or demonstrate complex tactics using MTC simulators like an "Omni-Max" theater.

Simulation also offers the capability to practice—not only through providing additional "flight time" for pilots, but also providing focused training for practicing specific tasks in need of additional training. Repeatedly practicing tasks achieves overlearning for tasks that need to become second nature.

Complex scenarios not easily orchestrated for flight training are very easy to design and conduct through simulation. DMT can create any environment with a multitude of realistic ground and air threats to better prepare pilots for air combat. Real-time kill removal will provide pilots with immediate and realistic feedback during each mission. Training for high-risk missions or dangerous tasks can also be accomplished without jeopardizing pilot safety

DMT Limitations

The privilege of simulation does not come without some drawbacks, however. Simulator studies identified several limitations for air combat training such as sources of negative training, and lack of physiological stresses or inputs that may be desired in training. Fortunately, none of the sources of negative training identified in the studies will be a factor for F-15C MTCs, which are expected to have superb visual projectors, threat behavior algorithms, cockpit hardware, and realistic weapons director radar screens. On the other hand, MTC simulators will not provide motion or other physiological stimulus and stresses that may be required to achieve desired training objectives. Pilots must learn to cope with the harsh environment of flight in fighter aircraft and acclimatize themselves to stresses such as Gs, vibrations, heat, exhaustion, altitude, and facing deathly consequences.

Ideally all sources of negative training would be avoided by matching training objectives with the training tool that provides all required stimulus and interactions. This does not imply that all training should be conducted in flight, since flight training carries its own restrictions. Whether the restrictions are due to safety, budget, airspace, or adversary constraints, these limitations should be viewed with the same concern as "sim-isms" because they may not expose pilots to needed training, or they may force pilots to train other than they would actually fight in combat.[1] When sources of negative training are unavoidable, the effects of negative training can be reduced through good instruction, by reminding pilots how their training environment differs from the one they will face in actual combat.

Developing Training Programs

With an understanding of DMT benefits and limitations, F-15C units can begin to develop effective training programs. Simulator studies present some guidance toward this effort, offering several training program considerations to achieve the most effective results from simulator training. Studies suggested which tasks should be emphasized in DMT, how metrics can identify training needs, who is expected to gain the most benefit from DMT, and when to schedule DMT events to optimize training.

Tasks to emphasize in DMT are quite simply, those tasks not receiving sufficient training from flight sorties. Tasks expected to be training deficient are those not accomplished in flight training due to their danger or complexity, while other tasks may be insufficiently trained in flight due to flight restrictions from budget constraints, limited airspace, or operational tasks. Less obvious training shortfalls may be due to only fleeting opportunities during a sortie to practice a necessary skill, therefore not providing pilots with enough psychomotor time to fully develop proficiency. Difficult tasks or perishable skills may also require additional training time to master or more frequent exposure to maintain proficiency. DMT provides a unique capability to focus on such skills and practice them as required.

Metrics can also help identify tasks in need of additional training. Objectively measuring pilot or team performance variables (process measurements) can identify which variables are most often responsible for mission failure, highlighting their need for additional training. Using metrics to measure both DMT and flight training performance can determine which training device is best suited for a specific training objective. The same measures can be used to improve training scenarios and programs. Finally, metrics can help identify individual pilot or team training needs. (There is still much work to be done in developing useful metrics for these purposes. Appendix C discusses this topic in greater detail.)

Upgrading pilots or those pilots recently upgraded to a new flight qualification were identified in simulator studies as those expected to gain the most benefit from DMT. The ability to isolate new tasks for practice and to provide multiple exposures to new decision-making challenges makes DMT a logical choice for maturing new flight leads or instructors. Training profiles for DMT should also vary for each flight qualification to focus training on unique responsibilities at each level.

Finally, melding the two training methods (DMT and aircraft) into a cohesive training program requires proper scheduling to avoid diluting effects in learning. Diluting effects include improper sequencing and lengthy delays between related DMT and flight events. To gain the most benefit from DMT, tasks and missions should build in a logical progression, sequenced with similar flights, creating a synergy to increase the effectiveness of both DMT and flight training while reducing the negative effects of both.

Final Comments

This paper focused on the development of DMT for F-15C pilots at the operational unit level. Simulator study findings, along with other literature concerning simulator training, were used to collect important considerations for the F-15C community to be aware of as they incorporate the new DMT tool as part of their air combat training program. With these considerations in mind, units should be able to develop programs that exploit the potential benefits of DMT, while avoiding simulation limitations discovered in the past.

DMT simulation presents new opportunities for air combat training. MTC simulators should be treated neither as aircraft, nor as typical simulators—DMT is unique, having capabilities that can be exploited to create complete, effective training programs, fostering combat-ready pilots.

Notes

[1] Dr. Herbert H. Bell, telephone conversation with author, 19 November 1998.

Appendix A

F-15C Mission Training Centers (MTC)

Advanced Simulators

F-15C operational units will be first in the CAF to incorporate Distributed Mission Training (DMT) advanced simulators. These simulators will have authentic cockpit controls, displays, avionics, weapons systems, ground handling, and flight modeling. Engine type will also be selectable to match variations in aircraft configuration. Simulator cockpits will have Full Field of View (FFOV) visual displays, providing an "out-the-window" cockpit view covering 360 degrees laterally and 135 degrees vertically. The display will even project an image of the F-15's wings and vertical tails. Aircraft details will provide enough aspect and distance cues to fly formation with a wingman out to two nautical miles, and in the future will include a night mode for Night Vision Goggle (NVG) training capability. The terrain features will replicate the local flying area or other selected real world regions, derived from standard Defense Mapping Agency products and services. This synthetic environment will provide not only visual inputs to the pilot, but also communication, navigation, and electronic inputs to operate all F-15C avionics and weapons systems.[1]

MTC Capabilities

Advanced simulators will be housed in a Mission Training Center. The F-15C MTCs at Eglin AFB and Langley AFB will each have 4 simulators that can be run individually, or linked for two-, three-, or four-ship operation.[2] An Instructor/Operator System (IOS) will control the links and mission scenarios, allowing instructors at the console to insert threats, emergency situations, weapons hit/miss data, atmospheric conditions, and more. Selectable private communication will allow instructors to comment to all or selected individual pilots in the simulators.[3]

The MTC can generate both constructive and interactive threats for its training missions. *Constructive* threats include computer-controlled aircraft, air-to-air missiles, surface-to-air missiles, and electronic systems. These threats will be programmed with real-world capabilities reported by the Defense Intelligence Agency (DIA) to provide realistic radar detection, weapons capabilities, and tactics.[4] Several *interactive* threat simulator stations in the MTC, which have very simple and generic cockpits, can be "flown" by additional pilots or instructors to provide human input to threat reactions and decisions for more realistic training. They too can be operated individually or linked into a scenario to generate multiple interactive threats.[5] The threats they represent are selectable from the IOS, not only giving opposing pilots the opportunity to visually identify the threat aircraft in close combat, but also appropriately restricting the weapons and radar capabilities of the interactive threat simulator to the known capabilities of the real-world threat.[6]

A radar intercept control station will also be installed in each F-15C MTC, which can be reconfigured to represent either a ground-based or AWACS director station.[7] A trained weapons director (WD) or a stand-in pilot can operate the station to provide control for F-15C pilots during each mission.[8]

MTCs will also include comprehensive briefing and debriefing facilities. In fact, the entire mission will be digitally recorded and can be replayed on large screens, showing a "God's eye" view of the entire mission. The system will have selectable scale and viewing perspectives to show terrain features, pilot views from various angles or other cockpit instrument displays for any selected pilot.[9] Aircraft data can also be paired to quickly show their relative altitudes, airspeed closure, and range from each other—similar to Air Combat Maneuvering Instrumentation (ACMI). In addition, each pilot's radar and heads-up-display (HUD) can be recorded on videotape for removal from the facility.[10]

Notes

[1] Contract, F33657-97-D-0025 Exhibit 1, "System Specifications for F-15C MSIP Simulation Service," 14 July 1997, revised 5 September 1997, 4-17.

[2] Air Combat Command, Operations and Training Branch (HQ ACC/DOTO), "Concept of Operations for F-15C Mission Training Centers," Working Draft, 29 September 1998, 29.

[3] Contract, 18-22.

[4] Air Combat Command, Operations and Training Branch (HQ ACC/DOTO), "Concept of Operations for Distributed Mission Training," 13 October 1998, 15.

[5] HQ ACC/DOTO, "Concept of Operations for F-15C Mission Training Centers," 11.

[6] Contract, 26-30.

[7] Ibid., 30-31.

[8] HQ ACC/DOTO, "Concept of Operations for F-15C Mission Training Centers," 11.

[9] Air Combat Command, "Systems Requirement Document (SRD) for the CAF F-15A/C MSIP Four-ship Simulator System and Aerial Combat Enhanced Simulation (ACES) Center," 28 March 1997, 8.

Notes

[10] Contract, 23-25.

Appendix B

Expansion of DMT

ACC intends to incrementally build upon the DMT base, linking the first two F-15C MTCs at Eglin AFB and Langley AFB with an AWACS MTC at Tinker AFB. The three MTCs will be networked through a Distributed Warfighting Center (DWC) "hub." The DWC location has not yet been determined, but its function will be to support the wide area network to conduct simultaneous distributed and stand-alone mission events. For example, the four-ship of Langley F-15C simulators can link with a two-ship of Eglin F-15s, controlled by a WD at Tinker—all working together in the same "synthetic battlespace." Meanwhile, the remaining two simulators at Eglin can conduct a mission with another WD at Tinker, or they can each conduct their own stand-alone missions.[1]

ACC will continue expanding DMT to include MTCs for every combat unit weapon system. An F-16 Block 50 MTC is already scheduled for completion in 2001. ACC has prioritized the rest of its weapons systems as either high, medium, or low in priority, based on the benefit crewmembers would gain from exchanging information with other weapon systems in a mission environment—there is no desire to add systems simply to act as training aids for others. High priority weapon systems include the A-10, F-15E, F-16 Block 40, E-8, F-22, JSF, and EC-130H

ABCCC and RC-135 Rivet Joint mission crews. Medium priority was assigned to F-16 Block 30, F-117, B-1, B-2, B-52, and EC-130E Compass Call mission crews. Within these categories, priority will go first to units most in need of upgraded simulators.[2] By 2006, all high and medium priority systems in the CAF (including forces in Europe and the Pacific) should be incorporated into DMT.[3]

The combined DMT network will have the capability to provide crew training at all levels, to include basic and high-end individual skills, team skills within a unit, and inter-team skills among multiple MTCs from all over the world.[4] The team building concept is particularly important for ACC, which is transitioning to organized Air Expeditionary Forces (AEF). AEFs combine squadrons from bases all over the world into pre-planned packages to deploy together if called upon for military contingencies. DMT will allow them to train together without having to physically collect themselves into a single location for exercises. The AEF plan is still being refined, but is currently planned for 10 AEF teams—two AEFs will be on call at any given time.[5] DMT will be able to replicate the terrain, weather, imagery, and opposition forces expected in the real-world theaters of operation, making it an ideal training aid for AEF pre-deployment preparation. Mission rehearsals can prepare units to work together before they ever have to encounter a real threat; they can also benefit commanders in developing options to counter various threat responses.[6]

Expansion of DMT will go even beyond the synthetic battlespace. Flight parameters and positions of real fighter aircraft can be tracked and relayed into the network by attaching specialized tracking pods to those aircraft. This capability has already been demonstrated, and the AWACS MTC has in fact already been used to control live-fly missions in airspace near Eglin AFB.[7] Although pilots in flight simulators may not coordinate directly with live-fly missions, command and control centers can combine both synthetic and live-fly missions for large-scale battlestaff training exercises.[8]

Notes

[1] Air Combat Command, Operations and Training Branch (HQ ACC/DOTO), "Concept of Operations for Distributed Mission Training," 13 October 1998, 11-13.

[2] Air Combat Command, "Roadmap for Distributed Mission Training (DMT)," Strawman, 6 July 1998

[3] Gen Richard E. Hawley, commander, Air Combat Command, keynote address at the Interservice/Industry Training, Simulation and Education Conference, Orlando, Fla., 1 December 1998.

[4] HQ ACC/DOTO, "Concept of Operations for Distributed Mission Training," 5-6.

[5] Hawley.

[6] HQ ACC/DOTO, "Concept of Operations for Distributed Mission Training," 7-8.

[7] Lt Col J. A. Bell, 33 OSS Current Operations Flight Commander, previously HQ ACC/DOTO F-15 Functional Manager, telephone conversation with author, 2 October 1998.

[8] Air Combat Command, Operations and Training Branch (HQ ACC/DOTO), "Concept of Operations for F-15C Mission Training Centers," Working Draft, 29 September 1998, 21.

Appendix C

Future Training Effectiveness Studies

Difficulty in Conducting TOT Studies

While TOT studies are theoretically the only sufficient test of simulator effectiveness, they are extremely difficult to coordinate and conduct. Simulator training is believed to be most effective for tasks difficult or impossible to practice in peace-time CT; attempting to demonstrate transfer for more common tasks tend to lead to only small effects, as seen in earlier TOT studies. Setting up in-flight tests for comparing experimental and control groups in operational units can also be extremely complex and burdensome. "In fact, one can argue that it is virtually impossible to conduct a well-controlled transfer test within an operational military environment."[1]

With the overwhelming response from survey and ISL studies that air combat simulation is valuable, there seems to be little reason to pursue further proof—especially considering the required effort and expected small effects. "Given the previous transfer of training research that has already been conducted ... there is little reason to suspect that such training within a multiship simulation environment *would not* have a positive effect upon subsequent performance in the air." (Emphasis in original)[2] A long-term study is more likely to provide measurable effects to compare DMT with comparable flight training. Results from a long-term study would provide valuable and reliable data to prioritize training tasks and the medium to use for various tasks, to determine the best combination of DMT and flight training.

Although it may be tedious, a long-term study tracking individual pilots or teams (flights, squadrons, wings, or AEFs) would be useful for identifying training strengths, deficiencies, or inefficiencies. Data could be collected during daily DMT and CT debriefings. At a minimum, data should be derived using objective measuring tools (discussed below) to track mission success or training effectiveness. In addition, data should include contextual information, such as: where pilots are in their career; what unit they're in; what training is available; what media is used for training and in what combination; and what constraints have been placed on flight training. With patience, a long-term study would provide a larger sample group for more reliable results, and provide a framework for better understanding how to achieve maximum training results with the available means.

F-15C MTC Training Effectiveness Study

Air Force Research Laboratory (AFRL) is tasked by the commander of Air Combat Command (COMACC) to investigate DMT effectiveness, transfer of RAP training elements, and "to determine the amount of credit that may be given for experience in the DMT environment."[3] The training effectiveness and RAP transfer investigations will be the combination of an in-simulator learning (ISL) study and a transfer of training (TOT) study, measuring pilot performance during all MTC and aircraft training, and comparing both MTC pre/post tests and aircraft pre/post tests. This information will be used to "determine which skills are better trained in the MTC ... which skills are better trained in the aircraft, and ... determine the transferability of these skills from the MTC to the aircraft."[4] The study will also provide input to the ACC/DO for the MTC accreditation decision to determine which RAP requirements can be accomplished in the MTC.[5]

For this upcoming study, AFRL is developing scenarios for MTC training designed to focus on "mission essential elements that should receive the highest level of attention"[6] due to their difficulty. Subjective and objective inputs were collected to determine which elements were most difficult to train. Subjective data came from subject matter expert (SME) inputs. Objective data came from ACC Form 206, flight lead upgrade (FLUG) gradesheets, collected during normal FLUG training at Eglin AFB. Unfortunately, there was difficulty identifying training shortfalls from the forms due to the tendency of instructors to grade events as "average."[7] (This problem was also mentioned in chapter three).

Regardless of how training shortfalls are identified, the concept of developing DMT scenarios to focus on identified training shortfalls should serve as a model for units developing MTC training profiles to meet their specific training needs. As a simple example, if sorting is identified as a shortfall, more heavy groups (with three or more threat aircraft) should be incorporated into training profile scenarios. If a more refined means can be developed for measuring performance and identifying training shortfalls, training profiles can be better designed to meet unit requirements.

DMT Long-Term Study

After AFRL conducts the MTC Training Effectiveness study, they will continue with a long-term DMT study. Although this study is "not yet specifically defined," it will "compare performance of pilots with similar experience levels in the aircraft, but different experience levels in the DMT environment through naturally occurring events such as Red Flag, Green Flag, and Weapons School attendance."[8] Ultimately the performance comparisons will help determine how much experience credit can be awarded to pilots for missions flown in DMT, and may result in a reallocation of flying and DMT hours. "Using information from all three areas of investigation, ACC/DOTO may be able to recommend a re-allocation of flying hours, in conjunction with simulation hours, that does not decrease aircrew mission readiness or aircrew safety."[9]

Finding Objective Measures

One of the major problems for future multiship simulator research is finding objective criteria to measure performance.[10] At this stage in research development, researchers are looking for ways not just to declare that performance has improved, but *how and why* has it improved. AFRL went through years of preparation and several independent studies to develop the behavioral indicators for SA Rating Scales (SARS) in their most recent ISL study.[11] The resulting behavioral indicators look remarkably like current F-15C gradesheets items used for upgrade training. They also resemble a briefing or debriefing outline used by flight leads and IPs on everyday CT flights. This similarity adds confidence that the processes listed are on the right track for measuring the component tasks required to achieve mission success.

For their upcoming F-15C MTC training effectiveness study, AFRL developed an even longer list of tasks to be graded, incorporating briefing, pre-push, ingress, egress, and debriefing elements. Although the list may be cumbersome to complete, these measurement criteria should provide valuable data for performance comparisons.

Soft Measures for Team Success

What behavioral indicators and the new list still fail to identify are the more subtle processes that must be learned and exercised to ensure *team* success—which is of utmost importance for DMT. Developed measures may still fall short of measuring true effectiveness. The high-payoff items in advanced simulators are things that make up *expertise*, which are hard to measure. Expertise involves team and collective behaviors (such as leadership or trust in the flight lead), and decision-making (such as gameplan and tactics selection, or changing the gameplan when things fall apart). Future tests may be satisfied with specifying sub-level motor skills and miss the more important "soft measures," where the real impacts are.[12]

Notes

[1] Wayne L. Waag and Herbert H. Bell, *Estimating the Training Effectiveness of Interactive Air Combat Simulation*, report no. AL/HR-TP-1996-039 (Mesa, Ariz.: Armstrong Laboratory, Human Resources Directorate, February 1977), 6.

[2] Ibid., 7.

[3] Ronald D. Dunlap, "The Training Effectiveness Evaluation: Measuring the Effectiveness of Training in an F-15C Mission Training Center," Air Force Research Laboratory, Warfighter Training Research Division, n.d., 3.

Notes

[4] Ibid., 5.

[5] Air Combat Command, Operations and Training Branch (HQ ACC/DOTO), "Concept of Operations for F-15C Mission Training Centers," Working Draft, 29 September 1998, 22.

[6] Dunlap, 6.

[7] Dr. Ronald D. Dunlap, telephone conversation with author, 26 February 1999.

[8] Dunlap, 3-4.

[9] Ibid., 3.

[10] Michael R. Houck, Leslie A. Whitaker, and Robert R. Kendall, *An Information Processing Classification of Beyond-Visual-Range Air Intercepts*, report no. AL/HR TR-1993-0061/AD A266927 (Williams Air Force Base, Ariz.: Armstrong Laboratory, Aircrew Training Research Division, May 1993).

[11] Wayne L. Waag et al., "Use of Multiship Simulation as a Tool for Measuring and Training Situation Awareness," in AGARD-CP-575, *Situation Awareness: Limitations and Enhancement in the Aviation Environment* (Neuilly-Sur-Seine, France: Advisory Group for Aerospace Research and Development, January 1996).

[12] Dr. Herbert H. Bell, telephone conversation with author, 19 November 1998.

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